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High Mobility Sixfold Valley Degenerate Electrons on Silicon [111] Surfaces[1]

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The 111 surface of silicon is predicted to retain the sixfold valley degeneracy of the ideal bulk crystal. We have developed a method for fabricating field effect transistors using vacuum as a dielectric in order to study electron transport on the bare hydrogen-terminated surface, free from the complications created by intrinsic disorder at Si-SiO_2 interfaces. The resulting devices display very high mobilities (up to 110,000 cm^2/Vs at 70mK, more than twice as large as the best silicon MOSFETs), enabling us to probe valley-dependent transport dynamics to a much greater degree than previously possible. Measurements made on a recent device over a density range of $n_s = 0.7 - 7 \times 10^{11}/cm^2$ reveal considerable information about the nature of this degeneracy and its role in 2D transport. In particular, we find (at n_s=6.7) that 1) low field Shubnikov-de Haas oscillations reveal a clearly sixfold degenerate system and allow us to establish an upper bound on the valley splitting of 0.2K 2) longitudinal resistivity at B=0 displays a strong temperature dependence, consistent with predictions that large valley degeneracy should enhance screening[1] and 3) the Hall coefficient near B=0 is modified by the presence of multiple valleys, and we can use this correction to measure the intervalley Coulomb drag and its temperature dependence. [1] E. H. Hwang and S. Das Sarma. PRB 75, 073301 (2007)

[1]This work was performed in collaboration with Tomasz M. Kott, Luyan Sun, and Bruce E. Kane of the Laboratory for Physical Sciences, University of Maryland at College Park and Kevin Eng of Sandia National Laboratories